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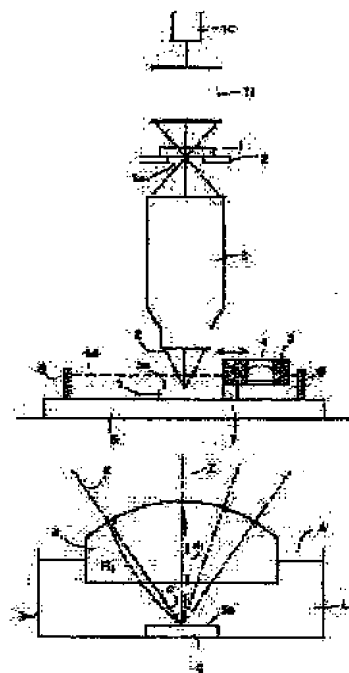
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## (54) PROJECTION ALIGNER AND EXPOSURE METHOD

### (57)Abstract:

**PROBLEM TO BE SOLVED:** To provide a projection aligner and method for reducing the change of image forming performance at an image forming position and in the neighborhood of an optical axis in a projection optical system, even when this projection optical system is used in an immersion state compared with the case that the projection optical system is used in a normal state.

**SOLUTION:** This projection aligner is provided with a projection optical system 2 for transferring a pattern 1a plotted on an original art 1 to a photosensitive face 5a of a substrate 5. An auxiliary lens 4 is arranged so as to be inserted into and pulled out of a space between the lens face at the substrate 5 side of the projection optical system 2 and the photosensitive face 5a, and a space between the lower face of the auxiliary lens 4 and the photosensitive face 5a is formed to be immersion possible. Also, a curvature radius R1 of the lens face at the original art 1 side of the auxiliary lens 4 is formed, so as to be almost equal to a distance d1 on an optical axis Z from the lens face at the original art 1 side to the photosensitive face 5a.



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**DETAILED DESCRIPTION**

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[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] This invention relates to the projection aligner and the exposure method of having the projection optics which carries out the printing imprint of the pattern drawn on the original edition on a substrate.

[0002]

[Description of the Prior Art] In recent years, detailed-ization of the pattern imprinted by the wafer as a photosensitive substrate is desired. In order to attain this, two methods, or [ whether short wavelength-ization of exposure wavelength is attained or / attaining increase-ization of the numerical aperture of projection optics ], can be considered. Before, the dipping-type projection aligner is proposed as a method of attaining increase-ization of the numerical aperture of projection optics among these. A dipping-type projection aligner is equipment of projection optics which fills space (it is henceforth called actuation space.) all of the lens side by the side of a wafer and space with a wafer, i.e., the working distance, (working distance), or the subspace by the side of a wafer with liquids, such as an oil, most. Usually, as opposed to the refractive index of the air which occupies the actuation space at the time of use being 1.0, the refractive index of an oil is about 1.6. For this reason, if all of actuation space or the subspace by the side of a wafer is replaced by the liquid with a refractive index high in this way, numerical aperture by the side of the wafer of projection optics can be enlarged, and detailed-ization of an exposure pattern can be attained.

[0003]

[Problem(s) to be Solved by the Invention] In the above-mentioned conventional dipping-type projection aligner, it is with the time of the dipping use to which actuation space is made into gases, such as air, and which attains the time of use, and detailed-ization of a pattern, and uses all of actuation space, or subspace by the side of a wafer as a liquid, and the equivalent image formation engine performance was not usually able to be secured. For example, the case where parallel plate glass is installed in the boundary of a gas and a liquid is considered as operation at the time of dipping which uses wafer flank part space of actuation space as a liquid. In such a case, the following three faults occur.

[0004] The 1st is fault from which the image formation location by projection optics shifts by the optical refraction in the plane of incidence of parallel plate glass at the time of dipping use. Therefore, it is necessary to move projection optics or a wafer so that a focal distance may be secured. And depending on the conditions at the time of the dipping use, an image formation location may not no longer be doubled on a wafer. The 2nd is fault which spherical aberration produces with the parallel plate glass installed in the boundary of a gas and a liquid at the time of dipping use. By this, the image formation engine performance worsens at the time of dipping use. The 3rd is fault to which change of the image formation engine performance at the time of dipping use or an image formation location becomes large by the environmental variation. That is, since the refractive index of a liquid changes with

environmental variations, such as a temperature change, a lot compared with a gaseous refractive index, neither the image formation engine performance nor an image formation location is stabilized by it. Therefore, this invention makes it a technical problem to offer the image formation location by projection optics, a projection aligner with little change of the image formation engine performance near an optical axis, and the exposure method compared with the case where it is used by the normal state, even when projection optics is used in the state of dipping.

[0005]

[Means for Solving the Problem] When a sign which it was made in order that this invention might solve the above-mentioned technical problem, namely, was given to drawing 1 and drawing 2 of an accompanying drawing is written in addition in a parenthesis, this invention In a projection aligner which has projection optics (2) which imprints a pattern (1a) drawn on the original edition (1) to a sensitization side (5a) of a substrate (5) Projection optics (2) is arranged most possible [ insertion and detachment of an attachment lens (4) ] in space of a lens side by the side of a substrate (5), and a sensitization side (5a). Space of an inferior surface of tongue of an attachment lens (4), and a sensitization side (5a) It is the projection aligner characterized by having been formed possible [ immersion ], and forming radius of curvature (R1) of the original edition (1) side lens side of an attachment lens (4) so that it may become almost equal to distance (d1) on an optical axis (Z) from the original edition (1) side lens side to a sensitization side (5a). When a sign further given to drawing 3 of an accompanying drawing is written in addition in a parenthesis in that case, as for radius of curvature (R2) of the substrate (5) side lens side of an attachment lens (4), it is desirable to be formed so that it may become almost equal to distance (d2) on an optical axis (Z) from the substrate (5) side lens side to a sensitization side (5a).

[0006] Moreover, this invention will be set to a projection aligner which has projection optics (2) which imprints a pattern (1a) drawn on the original edition (1) to a sensitization side (5a) of a substrate (5), if a sign given to drawing 1 and drawing 4 of an accompanying drawing is written in addition in a parenthesis. It is the projection aligner characterized by being formed so that projection optics (2) may become almost the equal to distance (d2) on an optical axis (Z) from a lens side by the side of a substrate (5) to a sensitization side (5a) as for radius of curvature (R2) of a lens side by the side of a substrate (5). Moreover, this invention is the exposure method characterized by to include a lighting production process which illuminates the original edition (1) with a predetermined exposure light, and an exposure production process which exposes a pattern image (1a) of the original edition (1) to a sensitization side (5a) of a substrate (5) through projection optics (2) in the method of exposing using a projection aligner of an above-mentioned configuration, when a sign given to drawing 1 of an accompanying drawing writes in addition in a parenthesis.

[0007]

[Embodiment of the Invention] A drawing explains the gestalt of operation of this invention. Drawing 1 and drawing 2 show the 1st example of the projection aligner by this invention. Drawing 1 is drawing by the 1st example of this invention usually showing the projection aligner in the time of use. \*\*\*\* 1 example carries out image formation of the image of pattern side 1a of a reticle 1 to image surface 5a (sensitization side) of a wafer 5 by the exposure method including a lighting production process and an exposure production process. That is, the flux of light emitted from the light sources 10, such as a KrF excimer laser, illuminates to homogeneity pattern side 1a of the reticle 1 as the original edition laid on the reticle stage 12 through the illumination-light study system 11. The exposure light emitted

from pattern side 1a of a reticle 1 carries out image formation of the image of pattern side 1a to image surface 5a of the wafer 5 laid on X-Y stage 8 through projection optics 2. In addition, at the time of use, actuation space usually says the condition of only air.

5 [0008] Here, on X-Y stage 8, the axis of rotation 7 is intervened and the attachment lens 4 held at the lens holder 3 is installed. This attachment lens 4 is pivotable centering on the axis of rotation 7. And if 180 degrees rotates from the location shown in drawing 1, an attachment lens 4 will be arranged just under projection optics 2. At this time, the optical axis of an attachment lens 4 is in agreement with the optical axis of projection optics 2. Moreover, the cube type-like liquid shield 6 is installed on X-Y stage 8. By drawing 1, since it is easy, only the cross section of the liquid shield 6 is shown. And liquids, such as an oil, can be put into the space surrounded by the liquid shield 6, and space can be used as a liquid by wafer 5 flank of actuation space. When using the projection aligner of \*\*\*\* 1 example in the state of dipping, an attachment lens 4 is arranged just under projection optics 2, and a liquid is put in in the liquid shield 6. At this time, it becomes air between the upper surface (field by the side of a reticle 1) of an attachment lens 4, and the inferior surface of tongue (most field by the side of a wafer 5) of projection optics 2. And it becomes a liquid between the inferior surface of tongue (field by the side of a wafer 5) of an attachment lens 4, and a wafer 5. The dashed line M of drawing 1 shows air and the boundary line of a liquid.

[0009] Drawing 2 is drawing in which it was expanded and shown near the attachment lens 4 in the projection aligner in the time of the dipping use by the 1st example of this invention. As mentioned above, in the time of dipping use, the space by the side of the upper surface of an attachment lens 4 serves as Air A, and the space by the side of the inferior surface of tongue of an attachment lens 4 serves as Liquid L. Moreover, the refractive index of the attachment lens 4 in \*\*\*\* 1 example serves as a value almost equal to the refractive index of Liquid L. The upper surface configuration of an attachment lens 4 is the configuration in which all the light K that carries out image formation to the center of image surface 5a on a wafer 5 carries out incidence perpendicularly. That is, an attachment lens 4 and Liquid L twist, and the center of curvature of the upper surface of an attachment lens 4 is usually in agreement with the center of image surface 5a at the time of use. And the radius of curvature R1 of the upper surface of an attachment lens 4 fills a degree type.

35  $R1=d1 (1)$

d1: Distance on the optical axis Z from the attachment lens 4 upper surface to wafer image surface 5a [0010] On the other hand, the inferior-surface-of-tongue

40 configuration of an attachment lens 4 has become plan type-like. As mentioned above, since the refractive index of an attachment lens 4 and Liquid L is equal, no light K which carries out image formation near the center of image surface 5a is almost refracted like the upper surface section also in the inferior-surface-of-tongue section of an attachment lens 4. Therefore, the convergence half width at the time of dipping use usually becomes equal to the convergence half width at the time of use. The refractive index [ as opposed to / at this time / the air of a  $NA=nsin\theta$ :liquid in the numerical aperture NA by the side of the wafer 5 of projection optics 2 ]  $\theta$ : It can be found in convergence half width. Moreover, resolution  $\delta r$  can be found in a degree type.

The refractive index k in the inside of the air of

50  $\delta r=k\lambda_0/NA\lambda_0$ :exposure light: Constant [0011] Therefore, compared with the time of use, resolution [ in / for numerical aperture / n times and near an image surface 5a center ] can usually be improved to  $1/n$  at the time of dipping use. Moreover, in the \*\*\*\* 1 example, since all the light K that carries out image formation

to the center of image surface 5a is not refracted depending on an attachment lens 4, spherical aberration does not generate it. Furthermore, when the chromatism of an attachment lens 4 and the chromatism of Liquid L are equal, axial overtone aberration is not generated, either. Thereby, in image surface 5a near optical-axis Z, even if it is at the dipping use time, the image formation engine performance at the time of use is usually maintained mostly. Furthermore, there are not the time of dipping use and change of the image formation location usually according to projection optics 5 by the time of use, either.

[0012] Next, drawing 3 shows the 2nd example of the projection aligner by this invention. \*\*\*\* 2 example differs only in the configuration of an attachment lens 4 from said 1st example. Drawing 3 is drawing in which it was expanded and shown near the attachment lens 4 in the projection aligner in the time of the dipping use by the 2nd example of this invention. The configuration of the upper surface section of the attachment lens 4 of \*\*\*\* 2 example is equal to the configuration of the upper surface section of the attachment lens 4 of said 1st example. That is, the relation of (1) type is realized in the upper surface section.

[0013] On the other hand, the configuration of the inferior-surface-of-tongue section of the attachment lens 4 of \*\*\*\* 2 example is a curved surface configuration to the inferior-surface-of-tongue section of the attachment lens 4 of said 1st example being a plan type-like. And the inferior-surface-of-tongue configuration is the configuration in which all the light K that carries out image formation to the center of image surface 5a on a wafer 5 carries out incidence perpendicularly like an upper surface configuration. That is, the center of curvature of the inferior surface of tongue of an attachment lens 4 is usually in agreement with the center of image surface 5a at the time of use. And the radius of curvature R2 of the inferior surface of tongue of an attachment lens 4 fills a degree type.

$R2=d2$  (2)

d2: Distance on the optical axis Z from attachment lens 4 inferior surface of tongue to wafer image surface 5a [0014] According to \*\*\*\* 2 example, even if it is a time of the refractive indexes of an attachment lens 4 and Liquid L differing, and a time of the refractive index of Liquid L changing with environmental variations, such as a temperature change, there is little change of aberration or an image formation location. That is, on the inferior surface of tongue of an attachment lens 4, no light K of the wavelength which carries out image formation to the center of image surface 5a is concerned with the refractive index and chromatism of Liquid L, and is not refracted. Therefore, also in \*\*\*\* 2 example, high resolution can be obtained like said 1st example at the time of dipping use. Moreover, even if it usually compares the time of use and dipping use, the image formation location by projection optics 2 does not change, but there is also no change of the axial overtone aberration in image surface 5a or spherical aberration, and the image formation engine performance in image surface 5a near optical-axis Z is maintained. Furthermore, even if the refractive index of Liquid L changes with temperature changes etc., there is no change of an image formation location, axial overtone aberration, or spherical aberration.

[0015] Next, drawing 4 shows the 3rd example of the projection aligner by this invention. Although a part of space was used as the liquid by wafer 5 flank of actuation space in said 1st and 2nd example at the time of dipping use, let all of actuation space be a liquid in the \*\*\*\* 3 example at the time of dipping use. namely, — the time of dipping use — projection optics 2 — the field by the side of a wafer 5 will be most dipped in a liquid. Therefore, the projection aligner of \*\*\*\* 3 example must have the upper surface of the liquid shield 6 of drawing 1 higher than the inferior surface of tongue of projection optics 2. Furthermore, the lens holder 3 of drawing 1 used at the

time of dipping use of said 1st and 2nd example, an attachment lens 4, and the axis of rotation 7 become unnecessary.

[0016] Drawing 4 is drawing of the projection optics 2 of a projection aligner having expanded and shown the field by the side of a wafer 5 most at the time of dipping use. projection optics 2 — the configuration of the field by the side of a wafer 5 is the equal to the configuration of the inferior-surface-of-tongue section of the attachment lens 4 of said 2nd example. That is, the relation of (2) types is realized in the inferior-surface-of-tongue section. Although the projection optics 2 shown in drawing 4 will usually be used on the other hand at the time of use, no refraction of Light K which carries out image formation near the center of image surface 5a is produced like the time of dipping use. Also in \*\*\*\* 3 example, high resolution can be obtained like said 2nd example at the time of dipping use. Moreover, even if it usually compares the time of use and dipping use, the image formation location by projection optics 2 does not change, but there is also no change of the axial overtone aberration in image surface 5a or spherical aberration, and the image formation engine performance in image surface 5a near optical-axis Z is maintained. Furthermore, even if the refractive index of Liquid L changes with temperature changes etc., there is no change of an image formation location, axial overtone aberration, or spherical aberration.

[0017]

[Effect of the Invention] By this invention, a projection aligner can be shared in the state of a normal state and dipping as mentioned above. And the projection aligner from which the image formation engine performance an image formation location and near an optical axis hardly changes at the time of dipping use can be offered.

Furthermore, few projection aligners and the exposure method of the effect of change of a refractive index of a liquid can be offered.

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## CLAIMS

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[Claim(s)]

[Claim 1] In a projection aligner which has projection optics which imprints a pattern drawn on the original edition to a sensitization side of a substrate Said projection optics is arranged most possible [ insertion and detachment of an attachment lens ] in space of a lens side by the side of a substrate, and said sensitization side. Space of an inferior surface of tongue of this attachment lens, and said sensitization side It is the projection aligner characterized by having been formed possible [ immersion ], and forming radius of curvature of an original edition side lens side of said attachment lens so that it may become almost equal to distance on an optical axis from this original edition side lens side to said sensitization side.

[Claim 2] Radius of curvature of a substrate side lens side of said attachment lens is a projection aligner according to claim 1 characterized by being formed so that it may become almost equal to distance on an optical axis from this substrate side lens side to said sensitization side.

[Claim 3] It is the projection aligner characterized by being formed in a projection aligner which has projection optics which imprints a pattern drawn on the original edition to a sensitization side of a substrate so that said projection optics may become almost the equal to distance on an optical axis from a lens side by the side of this substrate to said sensitization side as for radius of curvature of a lens side by the side of a substrate.

[Claim 4] An exposure method characterized by including a lighting production process which illuminates said original edition with a predetermined exposure light,

and an exposure production process which exposes a pattern image of said original edition to a sensitization side of said substrate through said projection optics in a method of exposing using a projection aligner of a publication in any 1 term of claim 1 thru/or claim 3.

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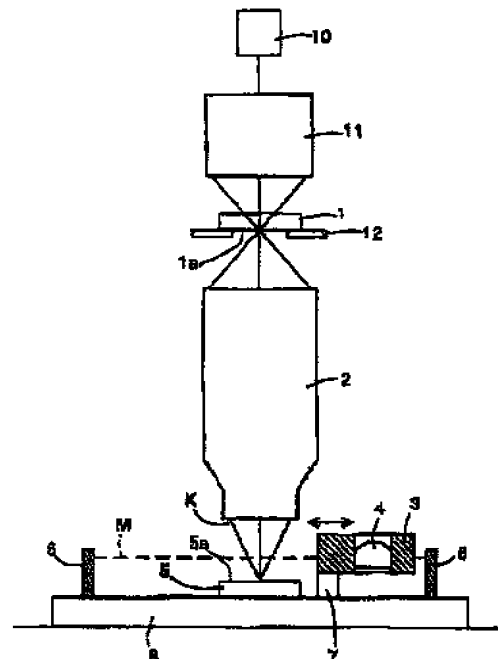
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(54) 【発明の名称】 投影露光装置及び露光方法

(57) 【要約】

【課題】 投影光学系を液浸状態で使用した場合でも、通常状態で使用した場合と比べて、投影光学系による結像位置と、光軸付近の結像性能の変化の少ない投影露光装置及び露光方法を提供する。

【解決手段】 原版1上に描画されたパターン1aを基板5の感光面5aに転写する投影光学系2を有する投影露光装置において、投影光学系2の最も基板5側のレンズ面と感光面5aとの空間に、補助レンズ4が挿脱可能に配置され、補助レンズ4の下面と感光面5aとの空間は、液浸可能に形成され、補助レンズ4の原版1側レンズ面の曲率半径 $R_1$ は、原版1側レンズ面から感光面5aまでの光軸Z上の距離 $d_1$ にほぼ等しくなるように形成される。



(2) 開2000-58436 (P2000-584JL)

## 【特許請求の範囲】

【請求項1】 原版上に描画されたパターンを基板の感光面に転写する投影光学系を有する投影露光装置において、

前記投影光学系の最も基板側のレンズ面と前記感光面との空間に、補助レンズが挿脱可能に配置され、該補助レンズの下面と前記感光面との空間は、液浸可能に形成され、

前記補助レンズの原版側レンズ面の曲率半径は、該原版側レンズ面から前記感光面までの光軸上の距離にほぼ等しくなるように形成されたことを特徴とする投影露光装置。

【請求項2】 前記補助レンズの基板側レンズ面の曲率半径は、該基板側レンズ面から前記感光面までの光軸上の距離にほぼ等しくなるように形成されたことを特徴とする請求項1記載の投影露光装置。

【請求項3】 原版上に描画されたパターンを基板の感光面に転写する投影光学系を有する投影露光装置において、

前記投影光学系の最も基板側のレンズ面の曲率半径は、該基板側のレンズ面から前記感光面までの光軸上の距離にほぼ等しくなるように形成されたことを特徴とする投影露光装置。

【請求項4】 請求項1乃至請求項3のいずれか1項に記載の投影露光装置を用いて露光する方法において、前記原版を所定の露光光で照明する照明工程と、前記投影光学系を介して前記原版のパターン像を前記基板の感光面に露光する露光工程とを含むことを特徴とする露光方法。

## 【発明の詳細な説明】

## 【0001】

【発明の属する技術分野】 本発明は、原版上に描画されたパターンを基板上に焼付転写する投影光学系を有する投影露光装置及び露光方法に関する。

## 【0002】

【従来の技術】 近年、感光性基板としてのウエハに転写されるパターンの微細化が望まれている。これを達成するためには、露光波長の短波長化を図るか、投影光学系の開口数の増大化を図るかの2つの方法が考えられる。従来より、これらのうち投影光学系の開口数の増大化を図る方法として、液浸式の投影露光装置が提案されている。液浸式の投影露光装置は、投影光学系の最もウエハ側のレンズ面と、ウエハとの空間、すなわち、作動距離（ワーキングディスタンス）の空間（以後、作動空間と呼ぶ。）の全部又はウエハ側の部分空間を、油等の液体で満たす装置である。通常使用時の作動空間を占める空気の屈折率が1.0であるのに対して、例えば、油の屈折率は約1.6である。このため、作動空間の全部又はウエハ側の部分空間を、このように屈折率の高い液体に置換すれば、投影光学系のウエハ側の開口数を大きく

し、露光パターンの微細化を図ることができる。

## 【0003】

【発明が解決しようとする課題】 上記従来の液浸式の投影露光装置においては、作動空間を空気等の気体とする通常使用時と、パターンの微細化を図り作動空間の全部又はウエハ側の部分空間を液体とする液浸使用時とで、同等の結像性能を確保できなかった。例えば、作動空間のウエハ側部分空間を液体とする液浸時の使用方法として、平行平板ガラスを気体と液体の境界に設置する場合を考える。このような場合、以下の3つの不具合が発生する。

【0004】 1つめは、液浸使用時、平行平板ガラスの入射面での光の屈折によって、投影光学系による結像位置がずれる不具合である。そのため、焦点距離を確保するように、投影光学系又はウエハを移動させる必要がある。そして、その液浸使用時の条件によっては、結像位置をウエハ上に合わせられなくなる場合がある。2つめは、液浸使用時に気体と液体の境界に設置される平行平板ガラスによって、球面収差が生じる不具合である。これによって、液浸使用時には結像性能が悪くなる。3つめは、環境変動により液浸使用時の結像性能や結像位置の変化が大きくなる不具合である。すなわち、液体の屈折率は、気体の屈折率に比べて、温度変化等の環境変動によって大きく変化するため、結像性能や結像位置が安定しない。したがって本発明は、投影光学系を液浸状態で使用した場合でも、通常状態で使用した場合と比べて、投影光学系による結像位置と、光軸付近の結像性能の変化の少ない投影露光装置及び露光方法を提供することを課題とする。

## 【0005】

【課題を解決するための手段】 本発明は上記課題を解決するためになされたものであり、すなわち、添付図面の図1及び図2に付した符号をカッコ内に付記すると、本発明は、原版(1)上に描画されたパターン(1a)を基板(5)の感光面(5a)に転写する投影光学系(2)を有する投影露光装置において、投影光学系(2)の最も基板(5)側のレンズ面と感光面(5a)との空間に、補助レンズ(4)が挿脱可能に配置され、補助レンズ(4)の下面と感光面(5a)との空間は、液浸可能に形成され、補助レンズ(4)の原版(1)側レンズ面の曲率半径( $R_1$ )は、原版(1)側レンズ面から感光面(5a)までの光軸(2)上の距離( $d_1$ )にほぼ等しくなるように形成されたことを特徴とする投影露光装置である。その際、更に添付図面の図3に付した符号をカッコ内に付記すると、補助レンズ(4)の基板(5)側レンズ面の曲率半径( $R_2$ )は、基板(5)側レンズ面から感光面(5a)までの光軸(2)上の距離( $d_2$ )にほぼ等しくなるように形成されることが好ましい。

【0006】 また本発明は、添付図面の図1及び図4に

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付した符号をカッコ内に付記すると、原版(1)上に描画されたパターン(1a)を基板(5)の感光面(5a)に転写する投影光学系(2)を有する投影露光装置において、投影光学系(2)の最も基板(5)側のレンズ面の曲率半径( $R_2$ )は、基板(5)側のレンズ面から感光面(5a)までの光軸(Z)上の距離( $d_2$ )にほぼ等しくなるように形成されたことを特徴とする投影露光装置である。また本発明は、添付図面の図1に付した符号をカッコ内に付記すると、上述の構成の投影露光装置を用いて露光する方法において、原版(1)を所定の露光光で照明する照明工程と、投影光学系(2)を介して原版(1)のパターン像(1a)を基板(5)の感光面(5a)に露光する露光工程とを含むことを特徴とする露光方法である。

【0007】

【発明の実施の形態】本発明の実施の形態を図面によって説明する。図1、図2にて、本発明による投影露光装置の第1実施例を示す。図1は、本発明の第1実施例による通常使用時の投影露光装置を示す図である。本第1実施例は、照明工程と露光工程を含む露光方法にて、レチクル1のパターン面1aの像をウエハ5の像面5a(感光面)に結像する。すなわち、KrFエキシマレーザー光源等の光源10から発した光束は、照明光学系1を経て、レチクルステージ12上に載置された原版としてのレチクル1のパターン面1aを、均一に照明する。レチクル1のパターン面1aから発した露光光は、投影光学系2を介して、XYステージ8上に載置されたウエハ5の像面5aに、パターン面1aの像を結像する。なお、通常使用時とは、作動空間が、空気の状態をいう。

【0008】ここで、XYステージ8上には、回転軸7を介して、レンズホルダ3に保持された補助レンズ4が設置されている。この補助レンズ4は、回転軸7を中心に回転可能となっている。そして、図1に示す位置から180°回転すると、補助レンズ4は、投影光学系2の真下に配置される。このとき、補助レンズ4の光軸は、投影光学系2の光軸と一致する。また、XYステージ8上には、箱形状の液体遮蔽板6が設置されている。図1では、簡単のため、液体遮蔽板6の断面のみを示す。そして、液体遮蔽板6に囲まれた空間に、油等の液体を入れて、作動空間のウエハ5側部分空間を液体とすることができる。本第1実施例の投影露光装置を液浸状態にて使用する場合、補助レンズ4を投影光学系2の真下に配置し、液体遮蔽板6内に液体を入れる。このとき、補助レンズ4の上面(レチクル1側の面)と、投影光学系2の下面(最もウエハ5側の面)との間は、空気となる。そして、補助レンズ4の下面(ウエハ5側の面)と、ウエハ5との間は、液体となる。図1の破線Mは、空気と液体の境界線を示す。

【0009】図2は、本発明の第1実施例による液浸使

用時での投影露光装置において、補助レンズ4の近傍を拡大して示した図である。前述したように、液浸使用時には、補助レンズ4の上面側の空間は空気Aとなり、補助レンズ4の下面側の空間は液体Lとなっている。また、本第1実施例における補助レンズ4の屈折率は、液体Lの屈折率とほぼ等しい値となっている。補助レンズ4の上面形状は、ウエハ5上の像面5aの中心に結像するすべての光線Kが垂直に入射するような形状となっている。すなわち、補助レンズ4の上面の曲率中心が、補助レンズ4及び液体Lがない通常使用時の像面5aの中心と一致している。そして、補助レンズ4の上面の曲率半径 $R_1$ は、次式を満たす。

$$R_1 = d_1 \quad (1)$$

$d_1$ : 補助レンズ4上面からウエハ5像面5aまでの光軸Z上の距離

【0010】一方、補助レンズ4の下面形状は、平面形状となっている。前述したように、補助レンズ4と液体Lの屈折率は等しいため、像面5aの中心付近に結像する全ての光線Kは、補助レンズ4の下面部においても、上面部と同様に、ほとんど屈折しない。したがって、液浸使用時の収束半角は、通常使用時の収束半角と等しくなる。このとき、投影光学系2のウエハ5側の開口数NAは、

$$NA = n \sin \theta$$

$n$ : 液体の空気に対する屈折率

$\theta$ : 収束半角

で表まる。また、分解能 $\Delta r$ は、次式で表まる。

$$\Delta r = k \lambda_0 / NA$$

$\lambda_0$ : 露光光の空気中での屈折率

$k$ : 定数

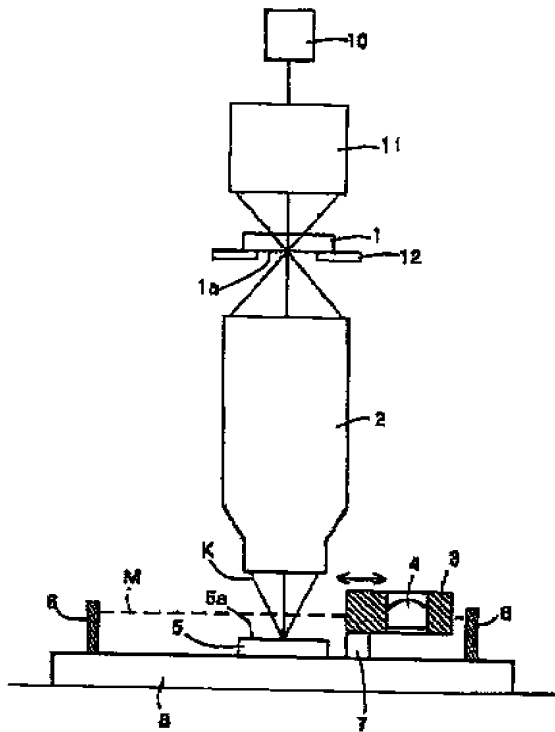
【0011】したがって、液浸使用時は、通常使用時と比べて、開口数を $n$ 倍、像面5a中心付近における分解能を $1/n$ に向上することができる。また、本第1実施例では、像面5aの中心に結像する全ての光線Kは、補助レンズ4によっては屈折しないため、球面収差が発生しない。更に、補助レンズ4の色分散と液体Lの色分散とが等しい場合には、軸上色収差も発生しない。これにより、光軸Z付近の像面5aにおいて、液浸使用時であっても、通常使用時における結像性能がほぼ保たれる。更に、液浸使用時と通常使用時とで、投影光学系5による結像位置の変化もない。

【0012】次に、図3にて、本発明による投影露光装置の第2実施例を示す。本第2実施例は、補助レンズ4の形状のみ、前記第1実施例と異なる。図3は、本発明の第2実施例による液浸使用時での投影露光装置において、補助レンズ4の近傍を拡大して示した図である。本第2実施例の補助レンズ4の上面部の形状は、前記第1実施例の補助レンズ4の上面部の形状と等しい。すなわち、上面部において(1)式の関係が成り立つ。

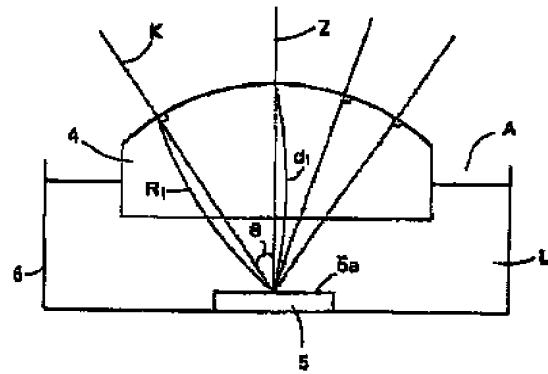
【0013】一方、前記第1実施例の補助レンズ4の下

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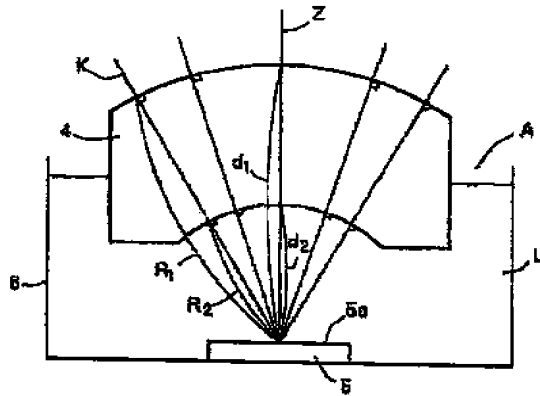
【図1】



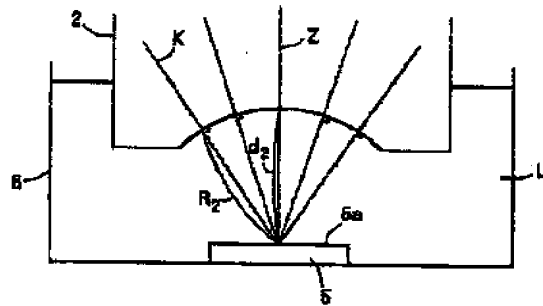
【図2】



【図3】



【図4】



フロントページの続き

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